RADIATIVE IGNITION AND TRANSITION TO SPREAD INVESTIGATION (RITSI)

Combustion Experiment

***Watching these flames in microgravity is just eerie.
They behave so differently than they do on the ground.
Hopefully, these investigations will make us safer in the future
and will teach us . . . about the basic process of combustion.
Glad we could help.***

Jeffrey Hoffman, payload specialist

INTRODUCTION

The **Radiative Ignition and Transition to Spread Investigation** (RITSI) studied the ignition process and the change from ignition to spreading flames in the presence of very slow air flows.

Information from this experiment expanded our knowledge of the conditions which will cause a material to ignite and spread. This information will enable scientists to design and implement fire detectors for the Space Shuttle and the International Space Station. In addition, this experiment will help scientists predict the way fire behaves on Earth.

This experiment was conducted aboard the Space Shuttle *Columbia* during flight STS-75 of the third United States Microgravity Payload (USMP-3) mission.

For information about similar experiments, see the Forced Flow Flame Spreading Test (FFFT) and the Comparative Soot Diagnostics (CSD) experiment which were also conducted aboard this flight. Also see the Candle Flames in Microgravity (CFM-1), the Smoldering Combustion in Microgravity (SCM), and the Wire Insulation Flammability (WIF) experiments which were conducted aboard the Space Shuttle *Columbia* during flight STS-50 of the first United States Microgravity Laboratory (USML-1) mission. Also see the second CFM and FFFT experiments which were conducted aboard the Russian Space Station during the *Mir* Increment 2 mission. Also see the Opposed Flow Flame Spread (OFFS) experiment which was conducted aboard the Russian Space Station during the *Mir* Increment 4 mission.

Fires, fires everywhere
And no time to burn.

Sandra Olson, co-investigator
Glenn Research Center

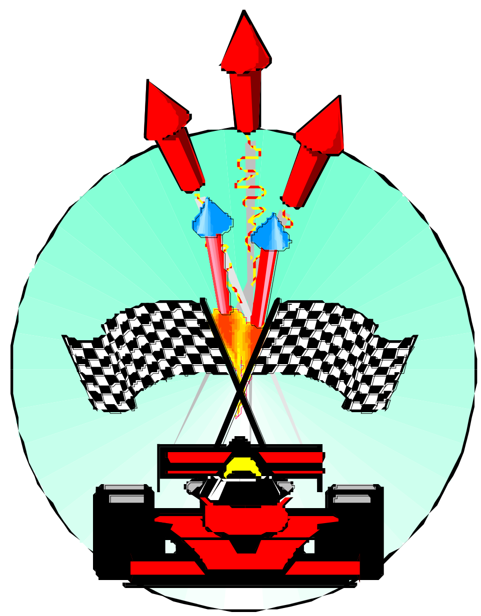
Ignition starts the race cars at the Indianapolis 500.

Ignition explodes fireworks on the Fourth of July.

Ignition kindles birthday candles, lights torches, and creates blazing fires on cold winter nights.

But wet matches don't light. Candles with short wicks snuff out. And without the proper kindling, campfires smoke and smolder without the first flicker of warmth.

On the surface, the change from spark to flame may seem simple. But the exact conditions for ignition are not yet well known.

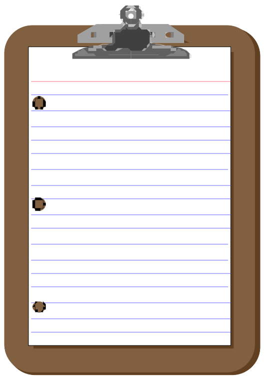


These conditions are especially important to spacecraft. On one hand, liftoff requires sparks to ignite the fuel and free the Space Shuttle from the effects of Earth's gravity. On the down side, unexpected sparks can also ignite electrical equipment. Flames can cause toxic fumes and gases which poison the air. These gases can also increase the cabin pressure and burst the spacecraft. Finally fire extinguishers can damage critical electrical systems.

While brief ignitions caused by electrical shorts or overheating may be quickly extinguished, spreading flames are unacceptable risks. To prevent this change from ignition to growing fires, researchers need to understand a fire's progression.

The Radiative Ignition and Transition to Spread Investigation studied this change from ignition to flame spread in microgravity.

The Objectives



- To study the behavior of flaming and smoldering ignition events.
- To study the transition from ignition to flame/smoldering spread.
- To study the flame/smoldering growth pattern in air.

The Hardware

I've been making fires since I was a Boy Scout. Then it was two sticks. Now it's two buttons.

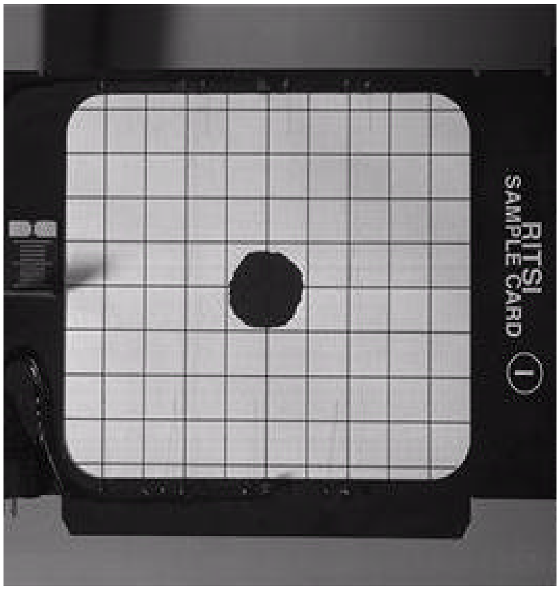
Jeffrey Hoffman, payload specialist

The hardware consisted of a flow duct, samples, and a parts box.

The flow duct was a box with screens at both ends and a fan for pulling the air through the box. The box provided a miniature wind-tunnel, with the fan varying the speed of the air.

The RITSI hardware, including experiment module and samples.

The samples were rectangular sheets of ashless filter paper.



Sample card.

Some samples were ignited along a central line which produced a flat, straight, two-dimensional flame spread.

Other samples were ignited at a central spot which produced a curving, outward, three-dimensional flame spread.

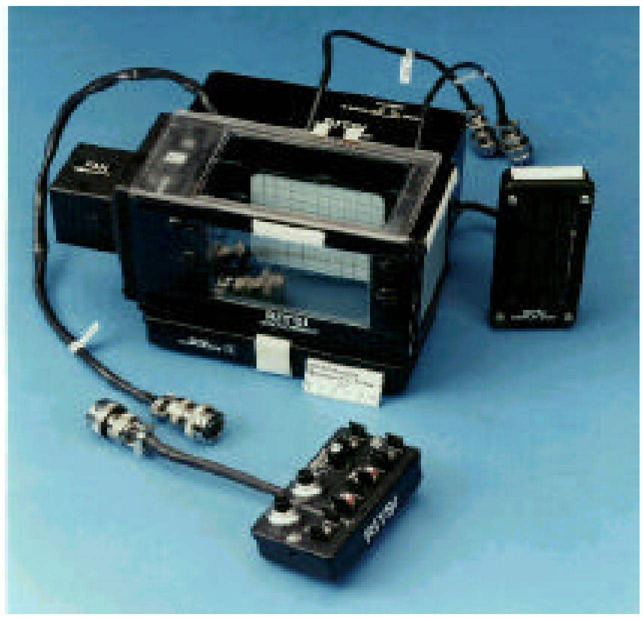
Additional samples were treated to cause smoldering rather than flaming.

Samples were attached to thin metal holders. Two methods were used to ignite the samples -- hot wires and heat lamps. Heat sensing devices recorded heater power, igniter power, and air flow speed.

A control box allowed the astronauts to manage the fan's speed, the igniter wire, the heater, the timing, and the lights.

The parts box stored the samples, cleaning supplies, and filters.

Video and 35 mm cameras recorded the process of ignition and flame development.



The RITSI module set up in the test configuration.

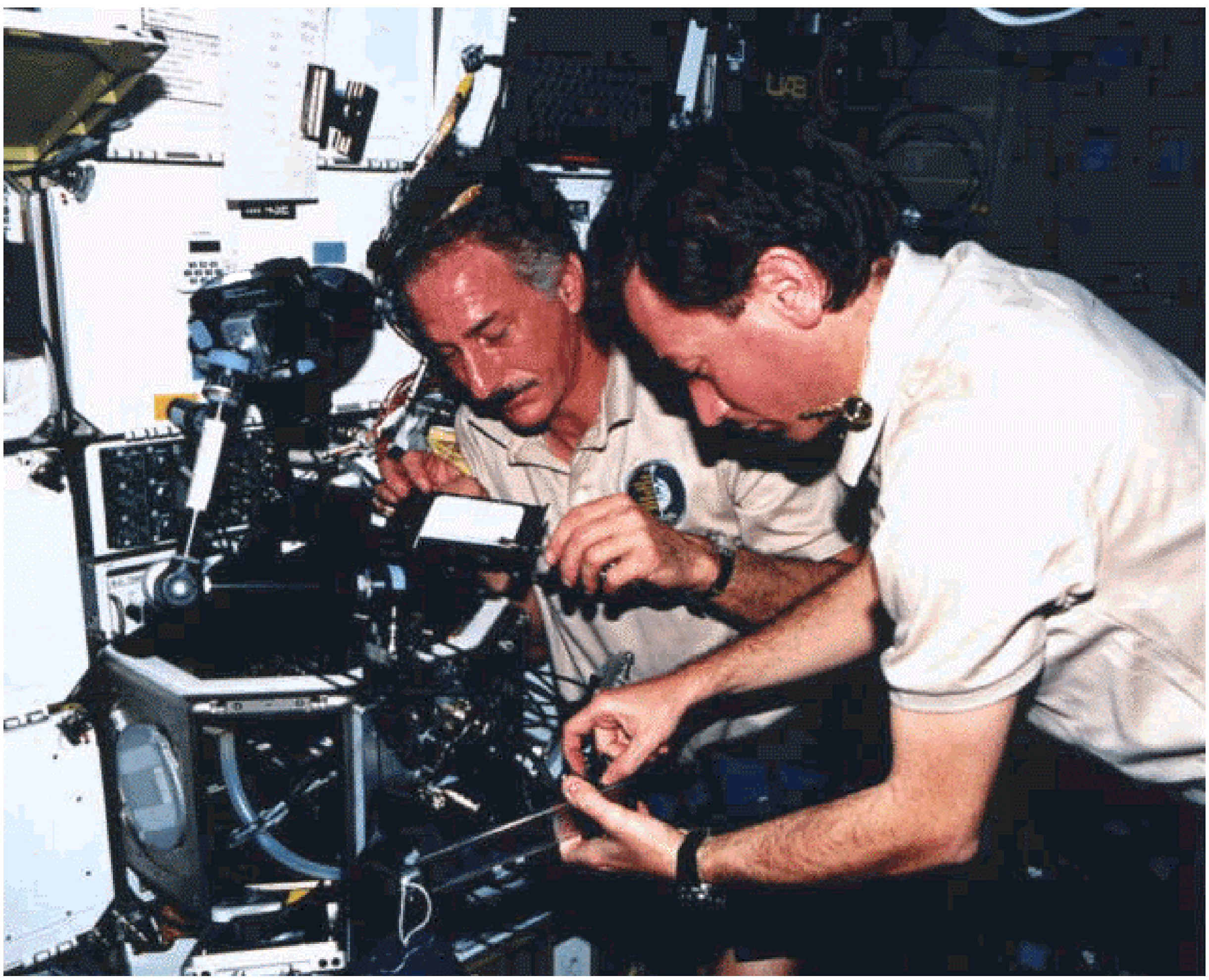
The Experiment

Mission Specialists Jeffrey Hoffman and Maurizio Cheli conducted the experiments.

After setting up the equipment in the Glovebox, and with cameras rolling, they ignited twenty-five samples.

During the experiment, the fan carried a slight breeze past each sample. These air flows were very weak, weaker than the air flows present in a room on Earth.

Between each test, investigators on Earth analyzed the information and fine tuned the conditions for the next test.

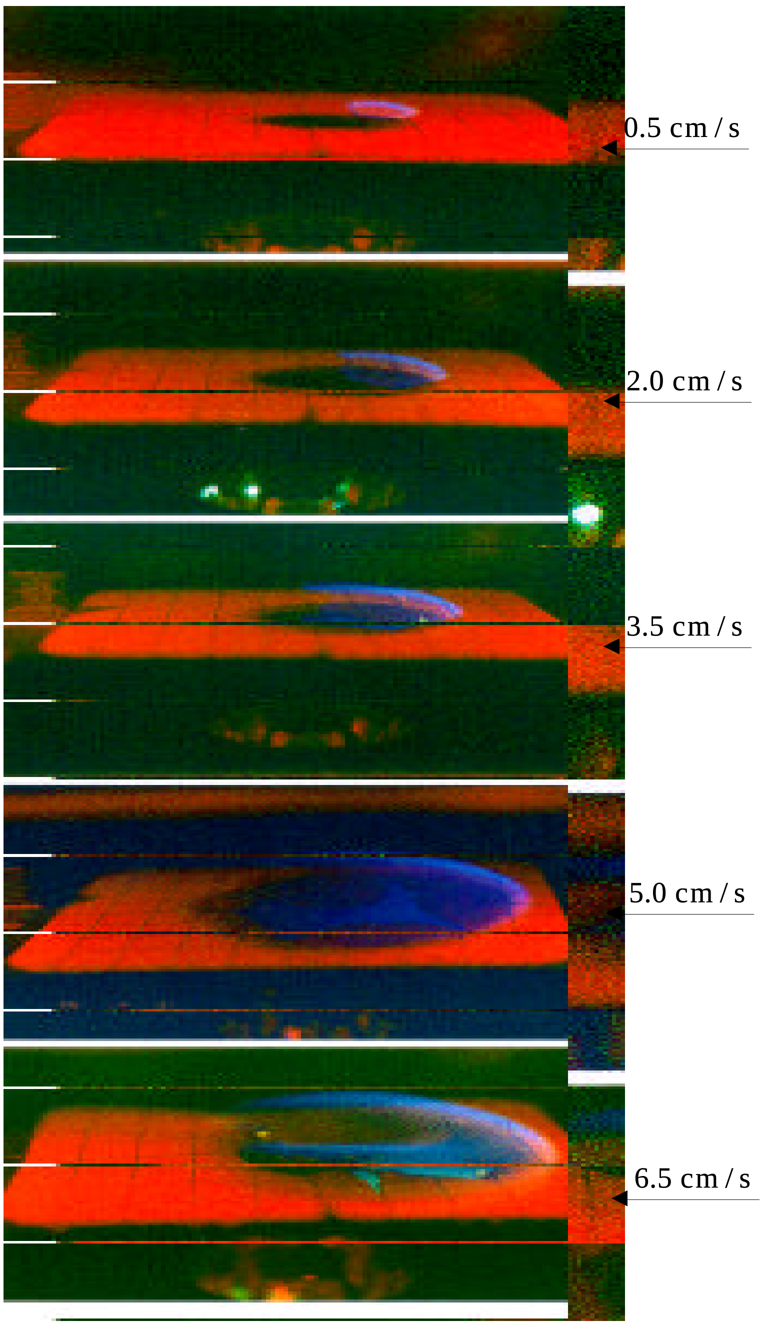


Jeffrey Hoffman and Maurizio Cheli perform the experiment.

THE RESULTS

Looks like a very interesting pattern.

Maurizio Cheli, payload specialist
European Space Agency



Flame shapes in varying air flows

Of the 25 experiments, 21 were flaming experiments, and four were smoldering experiments.

The shape of the flames depended on the air flows. In the flaming experiments, the flame preferred to move into the wind, exactly opposite from its behavior on Earth.

On Earth, buoyant air flows push the flame along with the wind. This is the reason wildfires rapidly spread uphill.

In microgravity, the oxygen supply is limited, and the flame seeksoxygen from the incoming air.

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In the smoldering experiment, a complex, unexpected finger-shaped char growth pattern was observed. Again, the smolder finger preferred to move upstream into the fresh oxygen. Increasing the air flow increased the number of fingers and the frequency of the fingers branching.

On Earth, a smoldering fire spreads outward in rings and consumes any material in its path.

In microgravity, the limited oxygen supply prevents smolder from growing too large. Since the smolder fingers use oxygen from all around them, the space between the fingers doesn't have enough oxygen to burn.

Finger-like smoldering instability in 2 cm/s flow.

THE CONCLUSIONS

The experiment produced crazy, unexplained smoldering phenomenon.

Takashi Kashiwagi, glovebox investigator
National Institute of Standards and Technology

The information from the experiment was compared to models and test data from drop tower experiments. Predicted flame shapes and spread rates agreed with the models and test data.

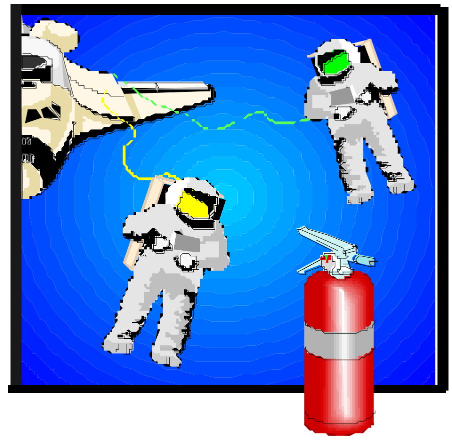
For example, in microgravity paper tends to ignite by heat more easily than on Earth. Also, flames spread much faster along the open edges of the paper than along the surface of the paper.

However, the smoldering fire produced unexpected, complex patterns when ignition was caused by a lamp. The nature of the smoldering fire could be extremely dangerous in space. The small tendrils could be hard to detect and would pollute the air with toxic fumes.

At the present time, the investigating team has concluded that each smolder fingertip casts an "oxygen shadow." An "oxygen shadow" is like a rain shadow on a mountain -- one side gets all the rain and the other side is dry. In the "oxygen shadow," the upstream side consumes all of the oxygen, while the downstream side doesn't receive any oxygen. "Oxygen shadows" are one possible explanation for the fingering smolder patterns.

Benefit to Quality of Life on Earth

While this experiment may improve fire safety in homes and industry, the information gained is more relevant to the safety of astronauts and their spacecraft.



Future Work

I can peek inside and I can tell you that it's incredible. They're really 3-D.

Maurizio Cheli, payload specialist
European Space Agency

Based on the RITSI results, a larger scale experiment is under development for flight aboard the International Space Station.

Named Transition from Ignition to Fire Growth Under External Radiation in 3D, or TIGER-3D, the experiment will have more sophisticated diagnostics to study the actual transition processes that govern a flame's successful ignition.

For Additional Information

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